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No. 846.

THE COAL HOISTS OF THE CALUMET AND HECLA MINING COMPANY.

By JULIUS KAHN, Jun. Am. Soc. C. E.

PRESENTED JANUARY 4TH, 1899.

WITH DISCUSSION.

The fact that large quantities of coal are consumed daily by manufacturing, mining, and commercial industries has necessitated the introduction of machinery especially adapted for handling this material. The loading of coal from cars into freight vessels, or from vessels into cars, has brought about the use of certain classes of this machinery—the unloading into coal storage sheds, and again the delivery from the sheds directly to the boiler stokers, has created the need of others. Hoisting and conveying machines to do this work are so varied in their construction to suit different conditions, that machinery of this class can in itself form a distinct branch of engineering.

The author has been unable to find in the *Transactions* any paper which has dwelt on this subject, and it has seemed to him that the description of one very large plant might possibly be of interest, and some of its engineering features worthy of special attention. The plant described was erected for the Calumet and Hecla Mining Com-

pany, during the months of June and July, 1898, at Lake Linden, Mich.

The Calumet and Hecla Mines are located on a peninsula, known as Kewenaw Point, and extending into Lake Superior. The smelting works and coal docks of the company are at Lake Linden, a small town situated on an inlet of Lake Superior; the mines are at Red Jacket and Calumet, Mich., two towns about 6 miles from Lake Linden.

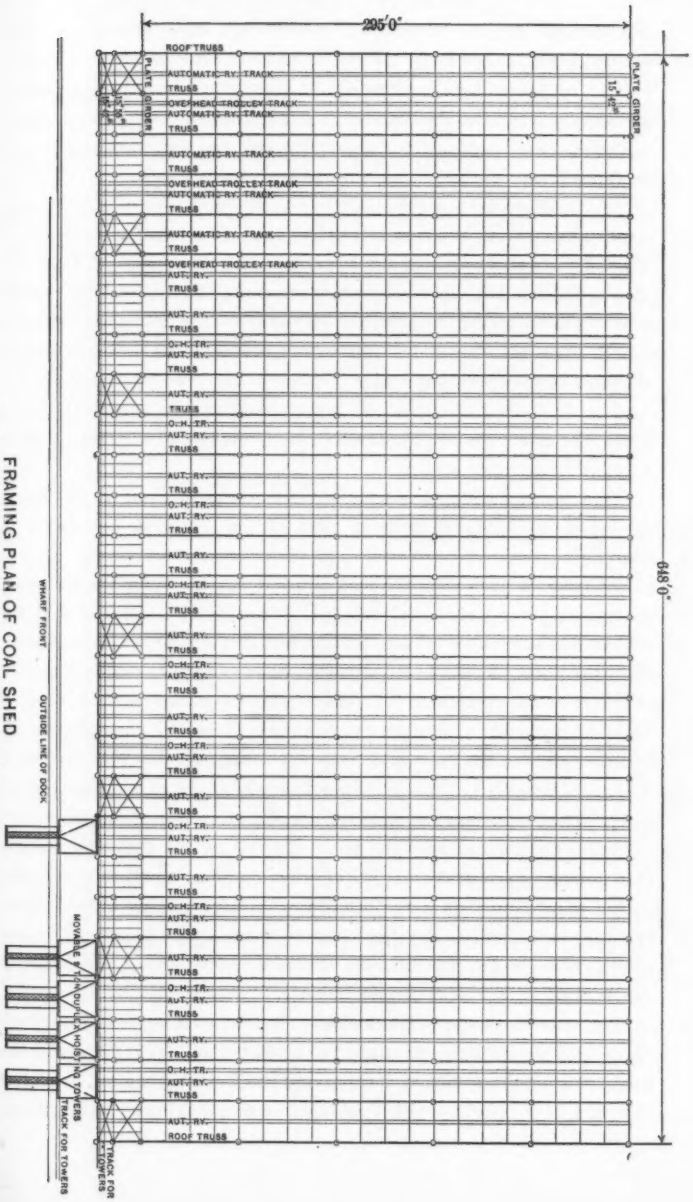
All coal is received from freight vessels at the docks in Lake Linden, and is hoisted there and conveyed into the coal storage sheds. It is carried from Lake Linden to the mines at Calumet by rail; the cars, entering passages provided for them in the sides of the sheds, are filled by special loading devices. The coal-carrying vessels from Buffalo to the upper peninsula have an average capacity of from 1 200 to 1 400 tons. They have usually five hatches, each about 8 ft. by 12 ft., and at 24 ft. centers.

The coal most commonly used is of the grades known as "Youghiogheny" and "Pocahontas," of Pennsylvania, and the "Soldiers' Run," of Virginia, all of which are large-lump, bituminous coals. There is also received a small quantity of anthracite, which serves for the domestic use of the workmen.

In 1894, the coal received by the company amounted to 225 420 tons; in 1895, 175 162 tons; in 1896, 207 000 tons; in 1897, 178 800 tons, and in 1898, 285 000 tons.

It can, of course, be easily appreciated, that even the slightest saving per ton for unloading this enormous quantity of coal from the boats, and conveying it to the coal sheds must amount to a large sum yearly, and, at a low rate of interest, must warrant a very large investment. Coal hoisting with a steam-shovel plant of this character, which takes the material from the hold of the vessel and delivers it into the storage sheds, is done at a possible cost of between 1 and 3 cents per ton. The same work done by stevedores would probably cost from 25 to 33 cents per ton.

The reasons for storing this immense quantity of coal are, primarily, to carry the works through a winter's demand, lake transportation being closed during this season; secondly, the company has found it necessary to make itself absolutely independent of possible accidents in the coal supply, caused by mine strikes and price



FRAMING PLAN OF COAL SHED

SHOWING LOCATION OF AUTOMATIC RAILWAY TRACKS.

FIG. 1.

fluctuations, and, to do this, has erected the steel-framed coal shed shown in Fig. 1, 648 ft. by 295 ft., to be used for storage or as a reservoir to be drawn upon in case any of the before-named causes make the supply less than the demand. The hoisting towers and automatic railways, which are used for unloading the coal from the vessels and carrying it into the sheds, are the subject of this paper.

Fig. 1, Plate II, is a side view of the hoisting towers and the coal shed, taken during erection and before the latter was enclosed. Fig. 2, Plate II, is a front view of the towers.

Fig 1, Plate III, shows the engine floors of the towers before they were enclosed with their housing, all the towers being close together. Fig. 2, Plate III, shows the engine floor of one of the towers, with the engineer at his operating stand.

Fig. 1, Plate IV, shows the wheel-bases of the towers. Fig. 2, Plate IV, is a view of the towers, completed, and several of them engaged in hoisting coal.

Figs. 2 and 3 show elevations of the towers and plans of the floors. A section and general framing plan of the building are shown in Fig. 1.

The towers have been reduced to great simplicity in their general design, and the individual members have been so placed that the theoretical strains are transmitted almost directly to the foundations. The rear posts have been battered to enlarge the base and increase the stability of the structures. It was impossible to increase the width of the towers beyond that shown in the front elevation, the distance between centers of the automatic railways being given as 24 ft., which it was not allowable to exceed. Each tower is mounted on five pairs of heavy wheels, is capable of being moved anywhere along the wharf, so that hoisting can be done from any one of the different hatches in a vessel, and if necessary all towers can be at work at one vessel at the same time. As the building in the rear contains 27 automatic railway tracks, and as any one of the towers is apt to unload on any one of the tracks, the extreme distance moved along the wharf is 648 ft.

The side elevation (Figs. 2 and 3) shows two floors, the upper one being used as the engine floor and the lower one as the car floor. On the upper floor is the receiving hopper and the hoisting engine; the latter is a 12 x 14-in. engine, with double drum and double cylinder, fitted

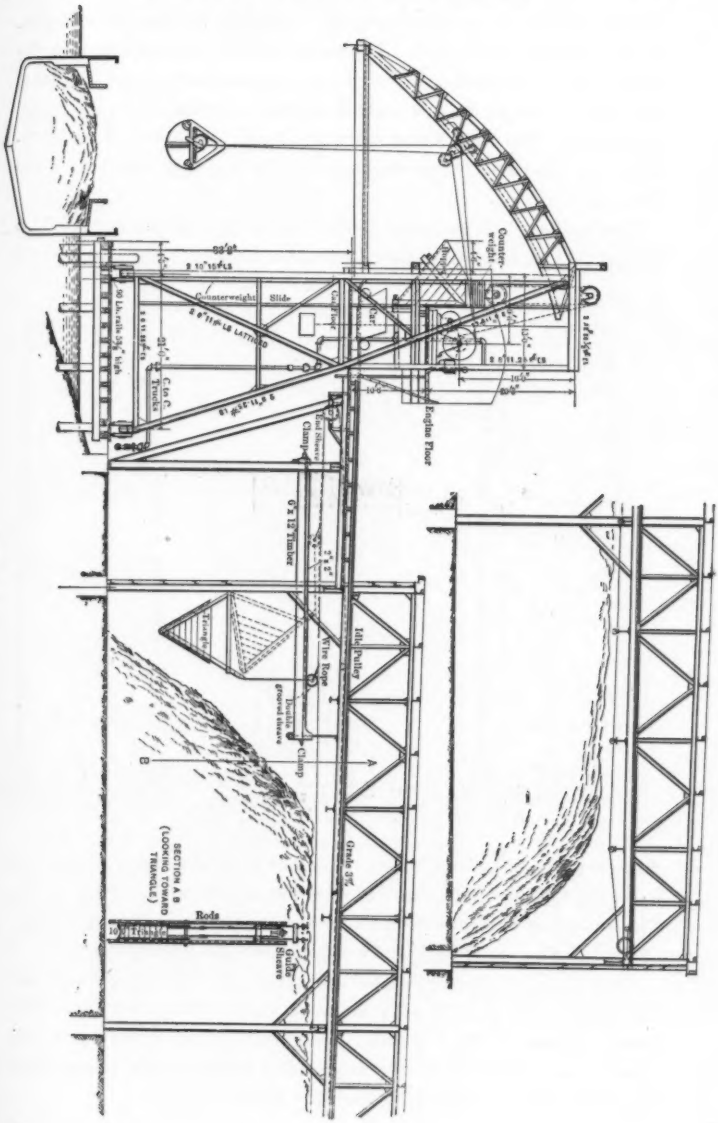

Counter-weight
Slide
Engine Floor
Clamp
Tail Sleeve
Wire Rope
Idle Pulley
Double grooved sheave
Clamp
Grade 3%
SECTION A B (LOOKING TOWARD TRIANGLE)
Rods
Guide Sleeve
A
B

FIG. 2.

with a steam brake, a steam reversing cylinder, an emergency brake, and a counterweight spool. Its drums are so constructed that the chains, which are laminated, wind upon themselves in a vertical plane; the reasons for this will be evident from the description of the boom, given later. The car floor contains the scale platform and the automatic car, the latter being stationed directly under a trap door in the hopper.

The plans of these floors show them to be heavily trussed in a horizontal plane and the rear elevation shows them to be trussed in a

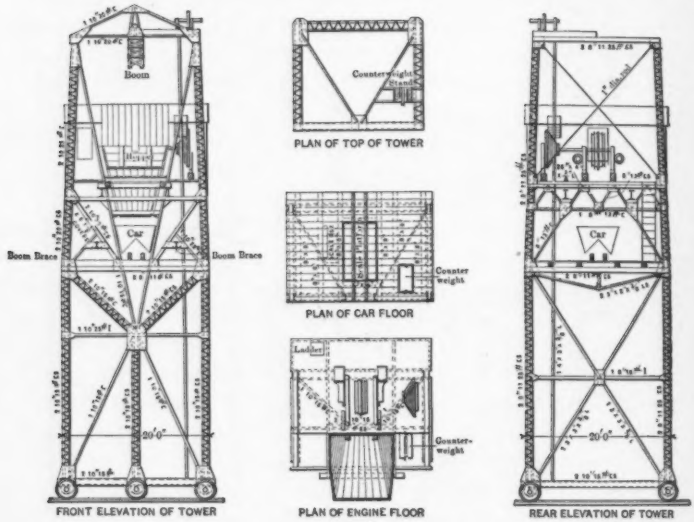
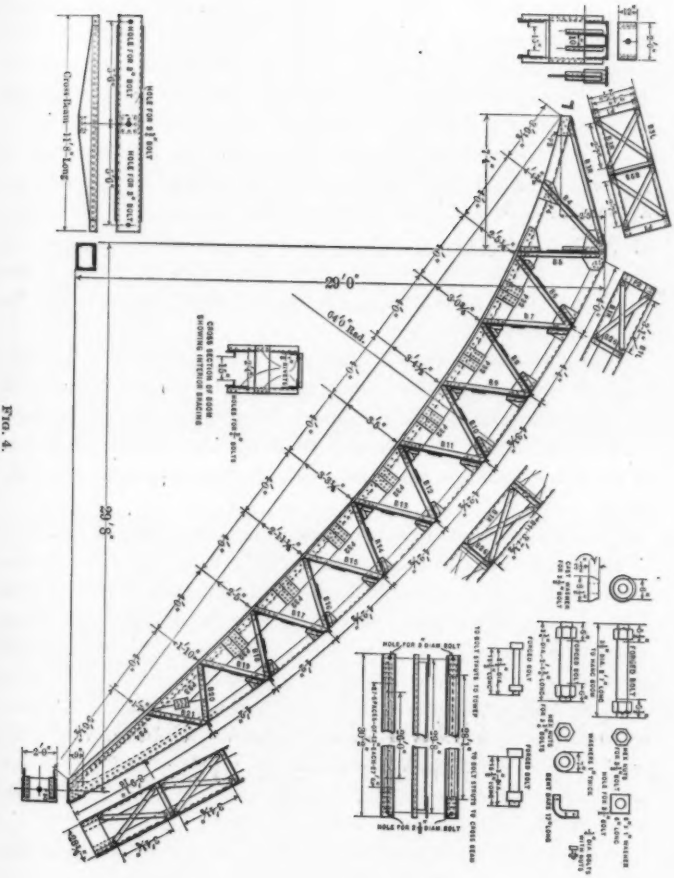


FIG. 3.

vertical plane. The truss under the engine floor takes up the load of the engine and the varying upward and downward pulls of the shovel chains. The horizontal truss under the floor receives the horizontal component of the hoisting chain pull, and carries it into the tower proper.

The boom is a heavily trussed structure, of a peculiar shape, the top chord being the arc of a circle of 64 ft. radius and the bottom chord approximately a parabolic segment. It is made up of two trusses, connected together by angles and plates in the plane of the top chord, and by bracing between the webs.


20'-0"
29'-8"
Cross Beams - 11'-6" Long
HOLE FOR 1" BOLT
HOLE FOR 1" BOLT
HOLE FOR 1" BOLT
CROSS SECTION OF FLOOR SHOWING INTERIOR BRACING
HOLES FOR 1" BOLTS
HOLE FOR 2 DIAM. BOLT
HOLE FOR 2 DIAM. BOLT
TO BOLT STRUTS TO TIMBER
TO BOLT STRUTS TO CROSS BEAM
FOUNDATION BOLT
FOUNDATION BOLT
FOUNDATION BOLT

The boom truck, containing the sheaves for the shovel chains, moves between the trusses, the flanges of the bottom chord acting as guides and rails. A chock block is used for arresting its downward travel. This is operated by a counterweight of its own, and automatically adjusts itself to different positions along the boom from which it may be desired to do hoisting.

A similar chock block at the upper end of the boom stops the truck directly above the hopper, and holds the same by a projecting hook when the truck is not in use.

At the farther end, the boom is connected to the cross-bar by means of a vertical pin, and transmits its horizontal stress into the same; the cross-bar is again connected by vertical pins with the horizontal braces. At its upper end, the boom is suspended from the top hip truss which is carried on cantilevered beams from the tower. This connection is also made with a large vertical pin. The details of the boom are shown in Fig. 4.

When hoisting is being done, the boom stands out at right angles to the front of the tower, and is held in this position by two guy lines attached to its sides. When not in use, it is swung around horizontally, approaching as nearly as possible to the face of the tower, thus allowing boats with high masts to move along the wharf.

The bottom chord of the boom was so designed that the resultants of the forces, when hoisting is being done at any point, are always normal to the track or bottom chord, a certain factor of safety or extra declivity being allowed for; this factor will be explained somewhat under the heading "Construction of the Boom." The resultant stress on the truck, being always in such a direction as to press it normally against the tracks, it has no tendency to run up the boom while the shovel is suspended from it. When the shovel reaches the truck, it bears on a suspended arm of the latter, and the chain now pulls both truck and shovel toward the tower and over the hopper, where the shovel is allowed to dump itself.

With this scheme of hoisting, where the shovel chains merely pass over the sheaves in the truck, it is of course easily seen that if the curve is not theoretically correct, and possesses a certain factor of safety, there is a tendency to slide the same either up or down the boom as soon as a pull comes on the chain.

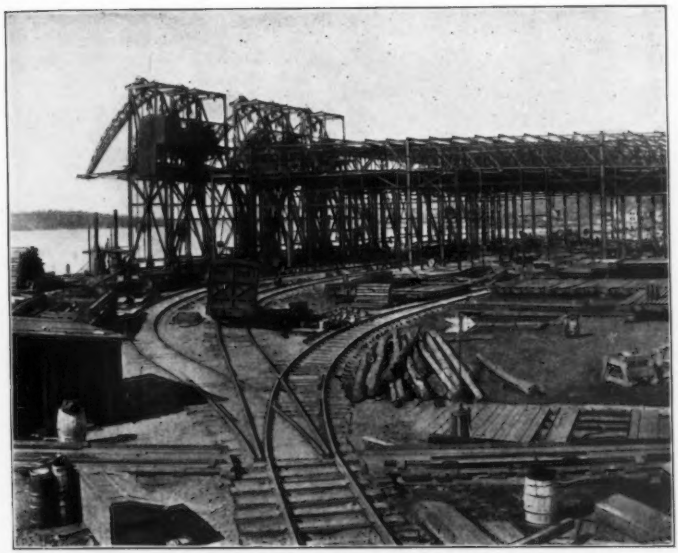


FIG. 1.

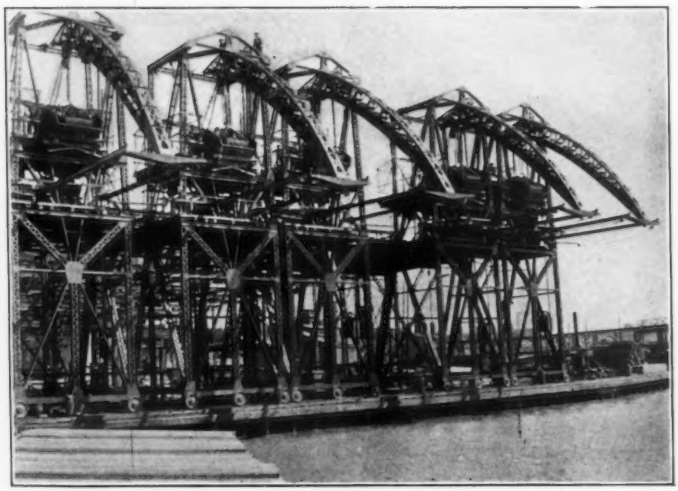


FIG. 2.

Operation of the Hoist.

The engineer is stationed at his operating stand at the front of the tower, as shown in Fig. 2, where he can at all times watch the shovel. He controls the throttle valve with a foot lever; the reversing gear is operated by a steam valve on his right, and the brake band by a steam valve on his left. There is also an emergency hand brake on his right. Two chains are used for operating the shovel, the hoisting and holding chains, both of them being of a laminated type, and made up of ten links.

Beginning with the empty shovel supported over the coal in the boat, the engineer sets his steam brake and supports the shovel on the holding chain. He then moves his reversing lever and allows the hoisting chain to become slack, the shovel opening by its own weight. As soon as the shovel has entirely opened, the engineer frees the brake band, and, with the engine reversed, allows the shovel to fall into the coal pile from a small height. The shovel by its own weight buries itself in the coal. The engineer, having the brake band set so that the holding chain drum is fixed, allows his engine to run forward and raise the hoisting chain. The scoops are thus forced together without exerting any tendency to lift the shovel out of the coal. As soon as the shovel is closed, the engineer frees the brake band of the holding chain drum and raises the shovel by both the holding and hoisting chains, slowing up a little as it approaches the boom, and from this point the shovel moves with the truck to the hopper. The engine is then stopped, and the shovel is suspended with the holding chain. The engine is reversed, which allows the hoisting chain to become slack, and causes the shovel to open and unload itself into the hopper. The shovel is again closed by winding up the hoisting chain; the brake band is released; the engine again reversed, and the shovel is allowed to descend the boom, and into the vessel.

It requires about 50 seconds to make one trip, and 2 tons are hoisted each time.

A man standing on the car floor below operates the trap door in the back of the hopper, and allows the coal to flow into the automatic car, which is stationed on the scale platform. He weighs the coal, and gives the car a slight push to start it down the incline of the automatic railway. It rushes along until at a certain point in its journey

it strikes the cross-bar, a strong oak frame laid across the track and connected by wire ropes with a triangular weight. The car picks up the cross-bar and drags it along, thereby raising the weight. Gradually, as the weight is raised, the energy of motion contained in the loaded car is transformed into the potential energy of the raised triangle. The cross-bar is located at such a distance before the point of dumping, that this energy of the loaded car has been entirely expended in carrying it to the dumping point. The car, therefore, when it arrives there is at a momentary standstill; its sides during the last few feet of motion have engaged the trip block and are caused to fly open. The coal is thus allowed to fall vertically into the shed, without any other component of force than that due to its height of fall, and this insures the least possible breakage of coal.

The car being empty, the raised triangle, possessing the energy of the loaded car, now descends, and forces back the cross-bar, thus giving the car an impulse sufficient to carry it back to the platform in the tower. All this work is done in a very short time, the car running down the grade with a constantly accelerated velocity, and returning with a constantly retarded velocity due to gravity.

Automatic railways of this character have been in operation for many years, especially where coal conveying is done to any extent. The entire arrangement works speedily, costs absolutely nothing for operating expense, is easily constructed, and has no delicate parts to be easily put out of order. A special and interesting feature of its mechanism is the device used to gradually retard the rapid descent of the car, changing its forward motion into a backward motion and giving just enough momentum to carry the car to the starting point.

The working of the triangle offers a very interesting mathematical study, in so far that its action is not the same as that of a falling weight; that its effective pull is of a varying nature, greatest and least at those points where it is most desirable to have it so, and that it receives and imparts great velocity with scarcely any shock or vibration.

The triangular weight is shown in Fig. 5, suspended from a double-grooved sheave which travels back and forth on a 6 x 12-in. timber track. The rope leads from the cross-bar, in one direction over a

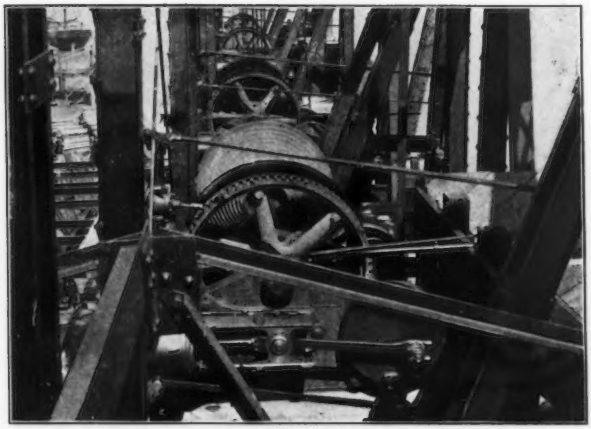


FIG. 1.

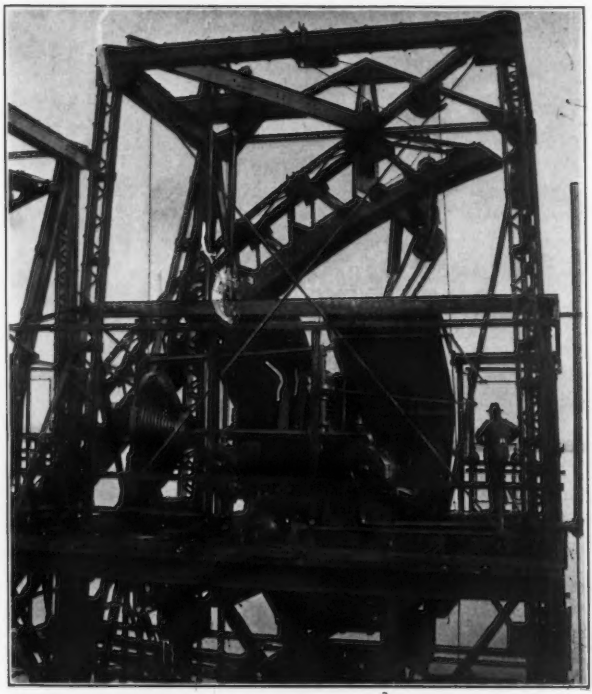


FIG. 2.

sheave at the end of the track, returns below the track to the triangle sheave, leads half-way over this, and is fastened to the end of the track timber pointing toward the rear of the shed. Leading in the other direction from the cross-bar, it passes around the other end sheave, returns below to the triangle sheave, takes a half turn about this and is fastened to the other end of the timber. It will be noticed, that at the instant when the car strikes the cross-bar, at which time its momentum is greatest, the triangle sheave is directly above one end of the triangle, and the force required to move it a very short distance, is theoretically zero if friction were neglected. As the cross-bar travels with the car, the triangle sheave is drawn forward along the timber track and the triangle is raised, its effective weight increas-

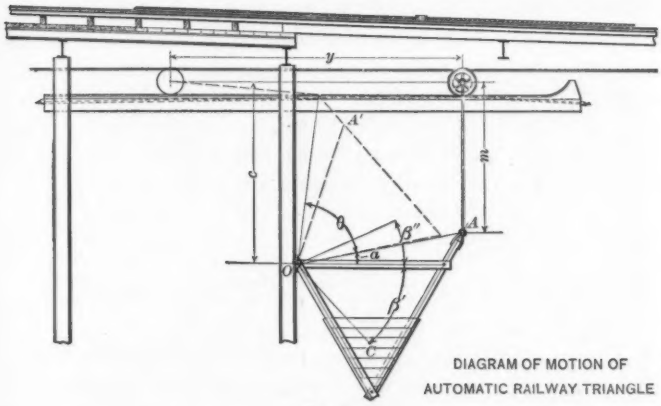


FIG. 5.

ing by a varying quantity. The car is thus gradually brought to a stop, at which instant the coal drops into the shed; then the backward push of the cross-bar on the car takes place, and from the entire effective weight of the triangle the backward push is gradually retarded, until the sheave is again directly over one end of the triangle, when it is reduced to nothing. As the backward push, however, is being retarded, the velocity of the triangle sheave and consequently that of the car is being increased; and at that point where the effective push of the triangle reduces to zero, the sheave velocity is at its maximum.

There is in the triangle and cross-bar a mechanism very nearly identical, in its rebounding effect, with that of the bow and arrow. At

the instant when the bow string is released, the component of string tension pressing on the end of the arrow is very large, and as this component decreases, the transverse velocity of the string increases, until at that point where the string is straight, its effective push is zero. Its velocity, however, is at a maximum, and is infinite as compared with the ends of the bow.

In the short mathematical discussion which follows, the author has deduced formulas to determine the following facts :

First.—Given the weight of the triangle, to derive the angular distance through which the triangle is raised and the distance through which the car drags the cross-bar ; or, given the distance through which the car drags the cross-bar, to determine the weight of the triangle.

Second.—Relative velocity of the rebounding car and falling triangle.

Third.—Real velocity of the rebounding car.

Fourth.—Frictional losses.

Let W = weight of empty car,

W' = weight of coal carried by car,

h = total fall of car from starting point to position of dumping,

δ = angle which rail slope makes with a vertical line,

w = weight of triangle,

w'' = weight of triangle sheave,

$r = O\,A$,

a = distance OC of center of gravity of the triangle from O, the center of rotation,

c = distance from the center of axle to center of triangle sheave,

y = horizontal distance of triangle sheave from its initial position,

θ = angle which any radial line from O makes with its initial position for any position of the triangle,

α = angle OA makes with the horizontal radius when in its initial position.

Total kinetic energy of descended loaded car = work done in raising triangle.

Work of swinging the center of gravity of the triangle through angle $d\,\theta = a\,w \cos\theta\,d\,\theta$.

First.—Total work of swinging the center of gravity of the triangle = $\int_{\beta'}^{\beta''} a\,w \cos\theta\,d\,\theta = a\,w\,(\sin\beta'' - \sin\beta')$, where β' and β'' are the initial

FIG. 1.

FIG. 2.

and final angles made by the radial line through the centroid with the horizontal radial line. But since total work done on the triangle equals total kinetic energy of the loaded car, $a\ w\ (\sin \beta'' - \sin \beta') = (W' + W)\ h$ and $\beta'' = \sin^{-1} \dfrac{(W' + W)\ h + a\ w \sin \beta'}{a\ w}$ .....(I)

This would be the true value for β'' if frictional losses were neglected.

Let f represent that part of the total height through which the car falls lost in friction of car travel, and v the greatest velocity of rebound of the car, then $\frac{v}{2}$ = the greatest velocity of the triangle sheave, and $\dfrac{w''\ v^2}{8\ g}$ is the energy lost in the sheave and dissipated in vibration through the timber and triangle.

Then

$$W'\ h = f + \frac{w''\ v^2}{8\ g}, \text{ and } \sin \beta'' = \frac{(W' + W)\left(h - \frac{f}{2}\right) + a\ w \sin \beta'}{a\ w}$$

or $$\beta'' = \frac{\sin^{-1}(W' + W)\left(h - \frac{f}{2}\right) + a\ w \sin \beta'}{a\ w} \text{.....(II)}$$

The total angle through which the triangle swings is $\beta'' - \beta'$

$$y = r \cos \alpha - r \cos (\alpha + \beta'' - \beta') + \sqrt{m^2 - [c - r \sin (\alpha + \theta)]^2} \text{.....(III)}$$

and when $\theta = \beta'' - \beta'$

$$y = r \cos \alpha - r \cos (\alpha + \beta'' - \beta') + \sqrt{m^2 - [c - r \sin (\alpha + \beta'' - \beta')]^2}$$

Drag of cross-bar then $= 2\ y =$

$$2\Big\{ r \cos \alpha - r \cos (\alpha + \beta'' - \beta') + \sqrt{m^2 - [c - r \sin (\alpha + \beta'' - \beta')]^2} \Big\} \text{.....(IV)}$$

To determine the weight of the triangle when the drag of the cross-bar is given, substitute the value of the latter in equation (IV), and solve for β''; then substitute the real value for β'' in equation (II), and solve for w.

Second.—From equation (III)

$$\frac{d\ y}{d\ \theta} = r \sin (\alpha + \theta) + \frac{[c - r \sin (\alpha + \theta)]\ [\cos (\alpha + \theta)]}{\sqrt{m^2 - [c - r \sin (\alpha + \theta)]^2}} \text{.....(V)}$$

Equation (V) represents the rate at which y changes with respect to θ or the relative velocities between the two. When $\theta =$ $\dfrac{d\ y}{d\ \theta} = \sin \alpha + \sqrt{\dfrac{r\ m \cos \alpha}{m^2 - m^2}} = \infty$.

When $\theta = 90° - \alpha$, $O\,A$ is vertical and A is in its highest position, and $\frac{d\,y}{d\,\theta} = \sin 90° = 1$.

Third.—Energy given up to ascending car $= \frac{W\,v^2}{2\,g}$. Energy lost in the triangle sheave $= \frac{w''\,v^2}{8\,g}$, then

$$\frac{W\,v^2}{2\,g} + \frac{w''\,v^2}{8\,g} = a\,w\,(\sin\beta'' - \sin\beta') - 2\,W\cos\delta\Big\{r\cos\alpha - r\cos(\alpha+\beta''-\beta') + \sqrt{m^2-[c-r\sin(\alpha+\beta''-\beta')]^2}\Big\} - Q\,..(\text{VI})$$

where Q represents that part of the total friction which has already been overcome, and where v is the only unknown quantity and can readily be computed.

Fourth.—Having determined v, since

$$W'\,h = f + \frac{w''\,v^2}{8\,g}, \quad \frac{f}{2} = \frac{W'\,h}{2} - \frac{w''\,v^2}{16\,g} =$$

frictional loss in ascent and descent of the car.

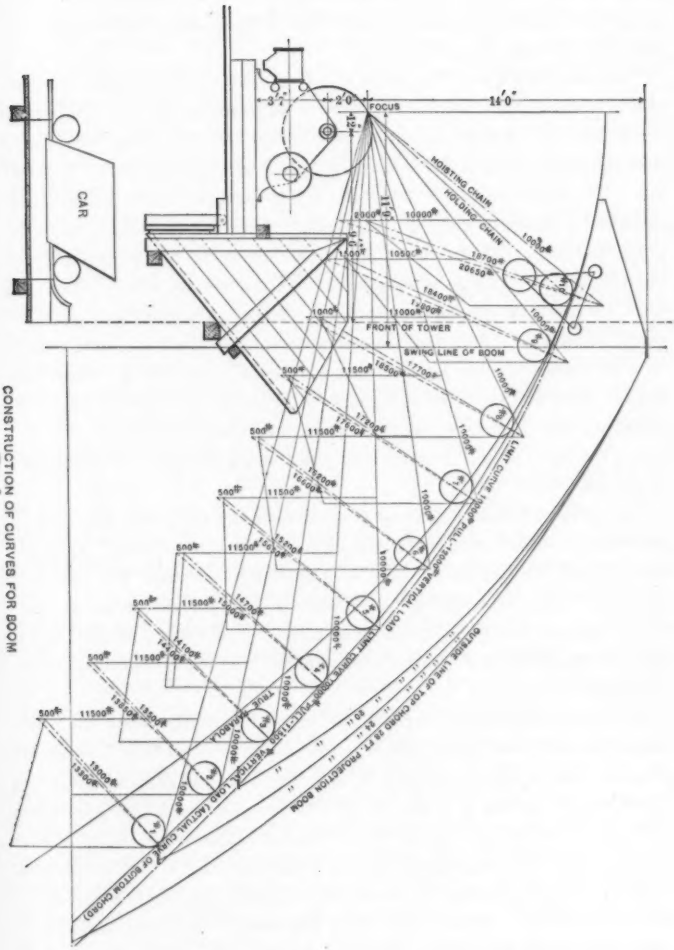
Equations (I), (II), (III) and (IV) indicate that the angular distance through which the triangle is raised, and the horizontal distance through which the cross-bar is carried, are directly dependent on the total weight of the loaded car, the triangle and the fall of the car.

Equation (V) gives the relation of the horizontal velocity of the triangle sheave or cross-bar to the angular velocity of the triangle, and shows that when the sheave is directly over one end of the triangle, or when the effective pull is zero, the relative velocity is infinite. When the end of the triangle is vertically above the axle, then the relative velocity is unity; or the end of the triangle, at this time, when the effective pull is greatest, moves with the same speed as the sheave. In all other positions during the fall of the triangle the sheave moves faster than the end of the triangle, the comparative velocity being represented by equation (V).

By equation (VI) the real velocity of the rebounding car can be determined for any position, either while it is still in contact with the cross-bar or after it has left it.

Construction of the Boom.

The construction of the boom represents a rather uncommon and decidedly interesting problem. Fig. 6 shows the construction of the curves for the 2-ton steam shovel booms. The latter are made in three


CAR
FOCUS
14'0"
HOISTING CHAIN
HOLDING CHAIN
FRONT OF TOWER
SWING LINE OF BOOM
CLOSE CURVE INNER PULL-FRONT VERTICAL LOAD
OUTSIDE LINE OF TOP CHORD 24 FT. PROJECTION BOOM
" " " " 20 " " "
" " " " 16 " " "
" " " " 12 " " "
" " " " 8 " " "
" " " " 4 " " "
TRUE CURVE
VERTICAL LOAD (ACTUAL CURVE OF BOTTOM CHORD)

CONSTRUCTION OF CURVES FOR BOOM
FIG. 6.

different standard lengths, so that hoisting may be done at a maximum projection of 20, 24 or 28 ft. The curve of the bottom chords is in all cases the same; the top chords are varied by making them arcs of circles of different radii. The booms of the plant described herein were of 28 ft. projection.

The small circles in Fig. 6 represent the sheaves for the hoisting chain in the boom truck when the latter is at its positions Nos. 1, 2, 3, etc.

The shovel weighs approximately 6 000 lbs., the coal 4 000 lbs., and the boom truck 2 000 lbs., making a total vertical load of 12 000 lbs. The chain pull is 10 000 lbs. If the weight of the boom truck could be neglected, the total downward force would at all times be equal to the pull of the chain, and if the direction of the chain from the truck to the engine were always toward a certain point, which has been assumed as the focus, the sides of the parallelogram of forces would always be equal, and the curve normal to the resultants would be a true parabola having its vertex approximately 12 ft. above the focus. This follows from the property of the parabola that the normal to the curve at any point will always bisect the angle included between the focal chord through that point and a line parallel to the axis of the parabola.

In the construction of these boom curves the chain was assumed to lead from the fixed point on the engine called the focus. This, although not theoretically exact, is sufficiently accurate for practical purposes. To have assumed the focus for each possible tangent position of the chain on the drum would have made the problem much more complicated and would have affected the final resulting curve very little.

If the vertical force exceeds the inward pull by 2 000 lbs., the weight of the truck, and if the curve is constructed so that it is at all points normal to this resultant, it will vary from the parabola, and the result will be the limit curve for 10 000 lbs. pull and 12 000 lbs. vertical load, as shown in Fig. 6. Since these resultants are more nearly vertical than the resultants for the parabolic curve, the 12 000 lbs. limit curve being normal to them, more nearly approaches the horizontal direction. This curve then represents the true theoretical curve, and if the focus is constant, as has already been assumed, the boom truck will be in an exact state of equilibrium during hoisting, neither rising nor falling, but being just on the point of balance.

The booms as actually constructed are made according to a third curve, shown in Fig. 6, about one-third of the distance between the 12 000 lbs. limit curve and the true parabola. In the third curve, the vertical loads are of a varying value. The curve is so constructed, or rather the vertical loads have been so modified, as to take into account the friction of the truck, allowing it to run down readily of its own accord from its highest position (No. 10) when dumping above the hopper. At all other positions of the truck a certain factor of safety exists, whereby a small weight is left to rest on the lower boom chock-block.

This overcomes the possibility of the truck sliding in too freely with the shovel toward the hopper, as a certain remaining downward force keeps the hoisting chain taut during this part of the shovel travel. In position No. 10 of the truck, the weight of the latter has been entirely neglected, and accordingly the curve is there a true parabola. Its grade is greater at this point than it need be, which insures the descent of the shovel with the truck down the boom; whereas with the true theoretical curve the shovel would descend into the hopper, instead of traveling with the truck when the hoisting chain is released.

For positions Nos. 9, 8, 7, 6, etc., the vertical loads have all been modified by amounts determined mostly by experience. The entire curve is somewhat less inclined than the parabola, and more inclined than the true theoretical curve. A curve has been constructed for which the rolling truck friction has been considered, and where a factor of safety is given to the travel of the shovel throughout.

There is another interesting feature about the construction of this curve. Assume, for example, that the shovel is held accidentally in the hatch of the boat, say, by a projecting bolt, or through carelessness of the workmen, or otherwise. In this case the engine may pull its maximum amount, which is 20 000 lbs., the vertical load will be 20 000 plus the truck weight; and since the resultant of this force parallelogram is less vertical than the resultant of the 10 000 — 11 500 lbs. limit curve, or the newly assumed curve, at this point, it has a component in the direction of the track, and the truck will slide a short distance up the boom, which, when noticed by the engineer, warns him to check the engine. There has been allowed in the curve, therefore, a factor of safety, which not only guards the shovel in its travel throughout, but which acts as a safety valve in case of danger.

The curve, although established theoretically, has been verified by the actual workings of the shovel, and the expected results have all been brought out in practice.

Boom Stresses.

It has seemed to the author that in a structure of this nature, where practically every condition exists that is prejudicial to its life, the assumed working strains should be of a most thoroughly conservative nature. The steam shovel is apt to be in operation in very cold weather, and this condition, when members have been heavily stressed, has accounted for the failure of many outdoor structures. Furthermore, there is scarcely a member in the boom which does not receive a repeatedly varying and sometimes rapidly reversed stress.

The short length of the truss emphasizes the need of taking into account this varying and reversal of stress, since the dead-load strains of the structure itself are very small compared with the live-load strains of the traveling shovel. A possible break in the boom is apt to be fatal to the structure as a whole, hence very small fiber strains have been assumed.

When it is considered what careless handling a steam shovel of this kind may receive at the hands of a workman, scarcely any assumed stress can be called too conservative, and where conditions of this kind are to be guarded against, the structure can scarcely be made too secure.

Again, the shovel may possibly be caught in the hatch of a boat and not be perceived by the engineer, in which case the engine would exert its maximum pull, a quantity much greater than that necessary to raise the shovel. To allow for this, all stresses have been computed for the maximum engine pull, irrespective of the loading in the shovel. This, of course, is greatly in excess of the actual working loads. The conditions under which the engine may be exerting its maximum pull are, however, quite possible, and, with a careless engineer and a small hatch, quite probable.

The assumed working stresses, from which the sections of the material have been determined, are as follows: These are based purely on the Weyrauch and Launhardt formulas, adapted to Wöhler's and Spangenburg's experiments. They have been modified slightly to agree more closely with the ultimate strength of the steel used in these structures.

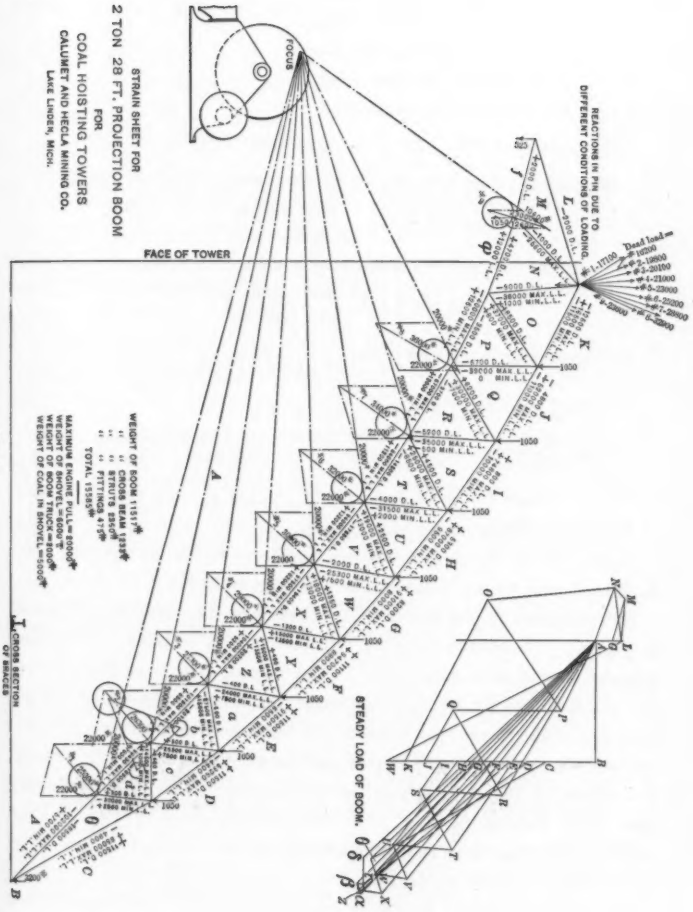

STRAIN SHEET FOR
2 TON 28 FT. PROJECTION BOOM
FOR
COAL HOISTING TOWERS
CALUMET AND HECLA MINING CO.
LAKE LINDEN, MICH.
FACE OF TOWER
FOCUS
REACTIONS IN PIN DUE TO DIFFERENT CONDITIONS OF LOADING.
Dead load = #10200
#-1-19800
#-2-20100
#-3-21000
#-4-22000
#-5-22200
#-6-22800
#-7-23000
STEADY LOAD OF BOOM.
WEIGHT OF BOOM 11510#
" " CROSS BEAM 1230#
" " STRUTS 2360#
" " FITTINGS 4150#
TOTAL 19250#
MAXIMUM ENGINE PULL = 8000#
WEIGHT OF BOOM TRUCK = 800#
WEIGHT OF COAL IN SHOVEL = 5000#
CROSS SECTION OF BRACES

Fig. 7.

Tension.—$8\,000\left(1 + \frac{\text{Min. stress}}{\text{Max. stress}}\right)$ for suddenly applied stresses of the same kind;

$8\,000\left(1 - \frac{\text{Min. stress}}{2\,\text{Max. stress}}\right)$ for suddenly applied stresses of opposite kinds;

$= 12\,000$ lbs. for dead load;

$= 16\,000$ lbs. for wind load.

Compression.—$8\,000 - 30\,\frac{l}{r}$ for live load.

For reversals of stress 8 000 lbs. is decreased as follows:

$$8\,000\left(1 - \frac{\text{Min. stress}}{2\,\text{Max. stress}}\right).$$

For varying loads of the same kind 8 000 lbs. is increased as follows:

$$8\,000\left(1 + \frac{\text{Min. stress}}{\text{Max. stress}}\right).$$

For dead load $= 12\,000 - 45\,\frac{l}{r}$.

For wind load $= 16\,000 - 60\,\frac{l}{r}$.

Rivets.—Loads suddenly applied $\begin{cases} = 6\,000 \text{ lbs. for shear,} \\ = 12\,000 \text{ lbs. for bearing.} \end{cases}$

Wind and dead load.... $\begin{cases} = 7\,500 \text{ lbs. for shear,} \\ = 15\,000 \text{ lbs. for bearing.} \end{cases}$

Fig. 7 is a strain sheet of the boom.

Table No. 1 shows the stresses in all members of the boom for dead load, and for all positions of hoisting, from No. 1 to No. 9.

The reaction at the upper end is taken by the vertical pin shown in Fig. 2. It is always inclined, thus setting up in the pin a bending moment as well as a direct pull. The varying nature of the stress in this pin is shown by arrows pointing in the direction in which the pin counteracts the forces which act on the boom and tend to pull it down; the length of the arrows corresponding to the quantity of stress. The effects of varying stresses on the pin are in this case very much like those usually coming on a steel spring, as they change from one direction to another, inducing alternating tensions and compressions in the extreme fibers of the pin.

The lower reaction is purely horizontal, and is also transmitted into the braces by vertical pins, the stresses varying also as above, but only reversed for one position of the truck, namely, No. 9. Table No. 1 shows the great variation in the stresses of all members.

TABLE No. 1.—MAXIMUM STRESSES IN THE BOOM, FOR THE DIFFERENT POSITIONS OF HOISTING.

Member.	Dead load.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
C Θ	+11 500	+ 85 000	+80 000	+ 72 000	+ 65 500	+ 56 500	+48 000	+34 500	+24 000	− 4 800
D C	+11 500	+ 54 000	+89 260	+ 80 000	+ 73 500	+ 64 000	+53 500	+43 000	+26 800	− 4 600
E a	+11 500	+ 39 000	+64 500	+ 91 500	+ 83 500	+ 72 000	+61 500	+52 800	+31 000	− 6 500
F Y	+11 100	+ 28 500	+48 300	+ 70 000	+ 94 700	+ 81 000	+69 300	+58 000	+35 000	− 8 800
G W	+ 8 200	+ 20 000	+36 000	+ 52 000	+ 72 000	+ 91 000	+71 700	+62 800	+38 500	− 8 000
H U	+ 5 300	+ 12 500	+25 500	+ 38 500	+ 52 500	+ 69 500	+87 000	+70 000	+44 000	− 9 500
I S	+ 800	+ 3 500	+14 500	+ 23 500	+ 35 000	+ 46 500	+60 500	+74 800	+47 500	−10 000
J Q	− 4 800	− 5 500	+ 2 500	+ 9 000	+ 16 700	+ 25 000	+39 000	+44 000	+52 000	−11 000
K O	−12 500	− 12 500	− 9 500	− 6 500	− 2 000	+ 2 500	+13 000	+13 000	+16 500	−11 500
L M	− 2 000	0	0	0	0	0	0	0	0	0
M N	− 1 000	0	0	0	0	0	0	0	0	−25 600
N O	− 9 000	− 11 700	−13 000	− 16 000	− 20 000	− 23 500	−28 000	−33 000	−38 500	+ 1 000
O P	+ 8 500	+ 10 000	+13 000	+ 16 500	+ 20 000	+ 23 000	+27 000	+32 000	+37 000	+ 800
P Q	− 6 700	− 11 000	−13 500	− 16 500	− 20 000	− 23 300	−29 000	−33 000	−39 000	− 0
Q R	+ 6 200	+ 10 000	+12 000	+ 14 500	+ 18 000	+ 21 300	+21 000	+30 000	− 7 000	+12 000
R S	− 5 200	− 10 000	−13 000	− 16 000	− 20 000	− 24 000	−25 000	−35 000	− 2 500	− 500
S T	+ 4 500	+ 8 300	+11 000	+ 14 000	+ 17 500	+ 21 500	+25 000	− 8 500	− 5 500	+ 1 200
U V	+ 2 500	+ 7 000	+ 9 000	+ 12 000	+ 16 000	+ 19 000	−13 000	− 9 300	− 7 000	+ 1 200
V W	− 2 000	− 8 000	−11 500	− 16 000	− 20 500	− 25 300	+ 7 500	+ 5 000	+ 4 000	− 600
W X	+ 1 350	+ 7 000	+10 000	+ 14 500	+ 18 000	− 13 000	−11 000	− 7 500	− 5 000	+ 1 400
X Y	− 1 300	− 9 700	−13 000	− 20 000	− 26 000	+ 6 500	+ 5 500	+ 2 800	+ 2 500	− 1 000
Y Z	+ 400	+ 7 500	+11 000	+ 15 000	− 13 500	− 11 500	− 9 500	− 6 500	− 4 500	+ 1 200
Z a	− 400	− 11 000	−17 500	− 24 000	+ 7 500	+ 6 000	+ 5 300	+ 2 500	+ 2 600	− 400
a b	− 600	+ 8 700	+15 000	− 27 500	− 11 600	− 9 500	− 8 500	−11 000	− 4 500	+ 1 000
b c	+ 500	− 15 500	−26 500	+ 7 500	+ 6 500	+ 5 000	+ 5 000	+ 5 500	+ 2 700	− 500
c d	− 1 400	+ 18 000	−14 500	+ 13 000	− 11 700	− 10 800	− 8 500	− 6 500	− 4 500	+ 1 000
d Θ	+ 500	− 30 000	+ 2 500	+ 2 000	+ 2 000	+ 2 000	+ 1 500	+ 1 500	+ 1 000	− 400
Θ *A*	−18 500	−102 000	−97 500	− 87 000	− 79 300	− 69 000	−58 000	−43 500	−29 000	+ 5 700
d A	−18 900	− 83 000	−98 430	− 88 000	− 80 500	− 70 000	−59 000	−44 500	−29 300	+ 7 000
b A	−20 100	− 64 500	−97 000	−101 500	− 92 500	− 80 700	−68 000	−51 000	−34 000	+ 8 500
Z A	−20 200	− 53 000	−73 000	− 95 800	−104 000	− 90 000	−76 000	−63 000	−38 500	+ 9 200
X A	−19 400	− 43 500	−60 000	− 76 500	− 97 500	−100 000	−84 500	−68 500	−42 500	+10 200
Y A	−17 650	− 35 500	−58 000	− 61 000	− 77 500	− 93 000	−94 000	−75 300	−47 000	+10 200
T A	−14 500	− 27 000	−37 000	− 46 500	− 58 000	− 70 000	−84 000	−81 300	−52 000	+11 200
R A	− 9 700	− 18 000	−25 300	− 31 000	− 39 000	− 47 000	−58 500	−67 000	−56 000	+12 000
P A	− 3 500	− 8 000	−13 000	− 15 500	− 20 300	− 24 000	−34 000	−35 000	−40 000	+12 600
N Φ	+ 4 700	0	0	0	0	0	0	0	0	−12 000
M f	+ 2 000	0	0	0	0	0	0	0	0	0
T U	− 4 000	− 9 500	−13 000	− 16 800	− 21 500	− 26 000	−31 500	+ 2 000	+ 2 000	− 400
Reaction upper pin { Hor.	+ 7 300	+ 12 000	+ 9 300	+ 6 500	.....	.....	− 3 000	− 6 500	− 9 500	− 8 500
Reaction upper pin { Vert.	−14 500	− 16 300	−17 500	− 19 000	−21 000	− 23 000	−25 000	−28 000	−31 500	−22 000
Reaction lower pin	+ 7 355	+ 30 500	+28 400	+ 25 700	+23 300	+ 20 000	+16 900	+12 890	+ 8 380	− 1 850

Taking, for example, such a member as "*A Z*", between positions Nos. 3 and 4 of the boom truck; the maximum live-load stress in this member is a tension of 104 000 lbs., when the truck is stationed at position No. 4. As the truck runs up the boom toward the unloading position, the stress decreases, and finally changes into a compression of 9 200 lbs., when the truck is stationed at position No. 9.

Furthermore, these stresses are not such as are induced in a bridge structure whose loading is more or less of a gradual nature, because in this case the live-load is applied in the truly theoretical way. As soon as the engine hoists, the load is there with its full effect. This condition seems to correspond precisely to Rankine's theoretical live-load. In bridge structures, repetitions occur only after long intervals, during which time the material of the structure has the opportunity to recuperate, as it may be called, or to return to its original molecular state, whereas in a structure of this nature, the truck runs over the boom with considerable speed, averaging one trip per minute.

The web members especially are subject to this fatigue of varying and reversal of stress. Take for example such a member as "*a b*." When the truck is in its position No. 2, this has a compressive stress of 15 000 lbs. live load, making a total compressive stress of 14 400 lbs. As soon as the truck leaves position No. 2, and arrives at position No. 3, the stress in "*a b*" is completely reversed from a large compression to a heavy tension.

In determining the sections of material of the boom it was primarily necessary to observe the variation just mentioned. In addition to this, however, it will be noted that there are a number of stresses of a different nature acting upon any one member of the structure. Take for example a member of the bottom chord "*Z A*"; there is first of all a direct tension of 94 800 lbs., which stress may be increased, or the unit stress decreased, in proportion to its variable nature as determined by the assumed formulas; secondly, the bottom chord, being a curved member, has thrown into it an eccentric stress, producing a bending moment, which tends to increase the tensile strain on the lower fiber of the chord, and decrease that on the upper fiber. A third strain, which is torsional, is induced in the member by the truck which travels on the flanges of the 6 x 6-in. angles of the bottom chord.

TABLE No. 2.—Tests of Structural Steel for Coal Hoisting Towers, Calumet and Hecla Mining Company.

Date.	Specimen.	Size in inches.	Area, in square inches.	Broke at pounds.	Strain, in pounds per square inch.	Limit of elasticity.	Limit of elasticity, in pounds per square inch.	Elongation in 8 ins.	Elongation; percentage of length.	Area of reduced section.	Percentage of reduction.
April 2..	6" x 4" x $\frac{7}{16}$" L	.860 x .636	.547	33 400	61 060	21 800	39 850	1.92	24	.260	52.4
" 2..	Web. 8" - 18 lbs. I	1.521 x .254	.386	25 900	67 090	17 700	45 850	2.08	26	.180	47.9
" 2..	Bar. 13" x $\frac{1}{2}$"	1.098 x .507	.557	34 000	61 040	21 700	38 950	2.12	26.5	.254	54.3
" 7..	⊔ Web. 10" 15 lbs.	1.820 x .254	.462	30 100	65 110	19 800	42 850	2.22	27.75	.211	54.3
" 7..	⊔ Web. 10" 15 "	1.016 x .256	.260	17 700	68 080	13 400	51 440	1.62	20.2	.131	50
" 7..	⊔ Web. 10" 20 "	1.410 x .328	.462	30 600	66 230	20 800	45 020	1.86	23.2	.227	50.8
" 9..	⊔ Web. 8" 11½ "	1.496 x .202	.302	18 400	60 920	12 100	40 060	2.2	27.5	.157	48
" 20..	L 4" x 3" x $\frac{3}{8}$"	1.265 x .378	.478	31 200	65 270	21 030	44 100	2.08	26	.244	48.9
May 2..	I Web. 8"-18 lbs.	1.514 x .248	.375	25 300	67 460	17 400	46 400	1.98	24.75	.192	48.8
" 2.	L 6" x 4" x $\frac{7}{16}$"	.740 x .648	.480	31 100	64 700	19 680	41 000	2.06	25.7	.232	51.6
" 2..	L 6" x 4" x $\frac{7}{16}$"	.780 x .716	.558	35 400	63 440	23 800	40 480	1.9	23.7	.312	44.1
" 2..	Pl. 13" x $\frac{3}{8}$"	1.024 x .408	.418	26 900	64 350	16 200	38 750	1.98	24.75	.204	51.2

Note.—Fracture silky, in all cases.

All top-chord members are subject to direct compression and bending moment due to eccentricity of the line of stress. All web members are subject first to a direct pull or compression, and secondly, to a bending moment produced by the tendency of the truck to spread the bottom chords.

It is hardly advisable to go into any of the steps of calculation here; the ways of proceeding are those given generally in books on the mechanics of materials. The reason the writer makes note of these things is that the union of all these stresses, combined with great variation and reversal, is rather uncommon in the ordinary run of structures.

The boom may perhaps be criticised as an uneconomical structure; but when all conditions are taken into account, and the successful working of the boom is considered, it is more difficult to suggest improvements than at first appears.

It is needless to discuss the strain sheets of the towers; these would only represent the results of computations in statics, and would resemble those of a cantilever bridge set vertically on one end instead of horizontally. Stresses throughout the tower are mostly of the same nature as those in the boom, *i. e.*, they are variable and sometimes completely reversed; only in this case the fixed weight of the tower with its engine, hopper, floor, loads, etc., forms a much greater portion of the total straining of the tower, and the immediate shocks from the steam shovel are not so readily felt. Unit stresses, therefore, determined by the assumed formulas, are much larger, and sections of material proportionately lighter.

Under certain conditions it is necessary to apply a downward reaction on the rear posts, and for this purpose heavy straps have been provided for anchoring the towers to the foundation rails.

Table No. 2 shows a few of the actual tests on the material.

The C. W. Hunt Company was the designer and builder of all the coal-handling machinery. The structural steel work of the hoists and coal shed was done by the Passaic Rolling Mill and the Union Bridge Company.

DISCUSSION.

GEORGE HILL, Assoc. M. Am. Soc. C. E.—The paper does not go into the economies of this plant, in that it does not state the capital cost, and therefore the interest and depreciation, as forming parts of the operating expense, are not known. The amount of wages per ton of coal handled, and the amount of fuel burned per ton of coal handled, are not stated. Mr. Hill.

There is no description of the method of generating and transmitting the steam, but judging from the plates, especially Plate III, Figs. 1 and 2, it would seem as though it were generated at some central plant, and transmitted through a pipe line to the traveling tower and to the cylinders of the hoisting engines.

The speaker may be in error, but, to him, this seems to be an exceedingly antiquated method of utilizing the energy of the combustion of coal, and a few calculations he has made seem to indicate a far more economical method of doing the work.

In the first place, to measure the work done, approximately 10 000 lbs. are lifted to a height of about 40 ft., which is 400 000 ft.-lbs.; then 12 000 lbs. are lifted to a height of about 25 ft., which is 300 000 ft.-lbs.; making a total of 700 000 ft.-lbs. The author states that a trip is made in about 50 seconds. Without serious error, this may be taken as one minute. The efficiency of the hoisting engine, apart from the thermo-dynamic efficiency of the steam, would not exceed 40%, which would give about 1 750 000 ft.-lbs. of work done by the engine; or, if it be assumed that the work is done in one minute, about 53 H.-P. The speaker's experience with engines of this type is that their water consumption per I. H. P. is about 150 lbs. Considering the length of pipe through which the steam has to be transmitted, the liability which exists therein for leaky joints and condensation losses, the fact that the engine is being constantly reversed, that it is in an exposed position, and that probably the cylinder drips are always slightly open to take care of condensation, it would seem that 150 lbs. is a very reasonable estimate. This will give about 14 lbs. of coal per minute, or for 2 tons of coal delivered on the pile. If coal is worth $4 a ton, the fuel cost per ton of coal delivered on the pile is 1.4 cents.

If, on the other hand, an electric motor were installed for handling the hoisting drums, the electricity being generated in a compound condensing plant, under cover, in some central location, and the apparatus controlled by some one of the usual and well-tested methods, the fuel cost per ton of coal would be about as follows: In the first place, the mechanical efficiency of the hoisting engine will be about 50 per cent. The work done is 1 400 000 ft.-lbs., and the resulting horse-power

Mr. Hill. is 42. As there are practically no line losses to consider, no losses from cylinder condensation, drips, leaky joints or anything of that sort, it may be said that a horse-power is delivered to the engine or the electric motor with the expenditure of about 30 lbs. per I. H. P.-hour, which gives 2.3 lbs. of coal per minute and a resulting cost for fuel, on the same basis as above, of about $\frac{1}{4}$ cent. So that there is quite a margin within which apparently the economy of the plant could be improved.

So far as concerns the cost of installation, the speaker believes that electric motors and a generator would have been fully as cheap as the steam plant, and the operating expenses would certainly be very materially decreased in the item of wages, for keeping up the pipe line, central station work, etc., as well as in the item of fuel. If the load due to the shovel and trolley was partially counterbalanced, it may be pointed out that whatever was practicable in that respect for the steam hoist would also be practicable for an electric hoist. Consequently the ratios of coal consumption and cost remain practically the same. The speaker does not advance those figures as being absolutely correct, but as being relatively so.

The speaker has no knowledge of any steam line of any length which has no steam losses due to leaking joints, and in such lines condensation losses are at least equal to 5% of the weight of the steam transmitted. Neither has he any knowledge of flexible steam pipe in which losses were not excessive so long as the pipe was flexible. If the transmitting steam pipe was proportioned in size to supply several hoisting towers simultaneously, the losses due to radiation would be proportionate to the size of the pipe rather than to the pounds of steam transmitted, and would, in consequence, be greater. The maintenance of such a pipe line in a proper condition would be an item of expense decreasing in amount as the installation charge increased.

In an electric transmission, on the other hand, there would be no appreciable transmission loss and practically no maintenance charge to be made. If the generating plant be considered, in each case, as independent, for the purpose of operating the unloading towers alone, the total wages account for the electric plant would be less than for the steam plant. If it be in each case considered as a part of a large central station generating power for a number of other uses, the cost of such power at the central station end of the transmitting device would be far less for the electric than for the steam plant.

The speaker uses $4 per ton as a convenient price, but the ratio would hold good for any price. The absolute amount of the saving that might be effected can be ascertained if the author adds to his paper all the items of expense heretofore mentioned by the speaker as being omitted.

O. J. MARSTRAND, M. Am. Soc. C. E.—The coal-handling plant in the free port of Copenhagen has five elevators for 2-ton steam shovels and thirty-six automatic tracks. The coal is stored in three pockets, each having a capacity of 10 000 tons, and in a yard having a capacity of 30 000 tons, situated immediately back of the pockets. Mr. Marstrand.

The plant is owned and operated by the Danish Coal Company. The machinery was designed by The C. W. Hunt Company, and built partly by them and partly by The Titan Company, of Copenhagen, who were the contractors for the entire plant.

With one or two exceptions, the machinery is identical with that described by the author, the differences being introduced to meet local requirements. One of these was that the coal should, at times, be unloaded from the steamers into barges brought up close to and on the farther side of them, which meant that the shovel should be run out to the end of the boom and there dumped. For this purpose a secondary or trolley engine was placed in the tower, its operating lever being brought to the operating stand of the main hoisting engine. A rope, attached to the boom truck, passed over a sheave at the outer end of the boom, to a sheave at the top of the elevator, thence around the drum of the trolley engine and back to the boom truck. In this manner the boom truck could be moved in and out from its position over the hatch of the steamer to a position from which the coal could be dumped through a hopper into the barge.

Another local requirement was that the dock on which the elevators moved should be kept clear for the passage of railroad cars, and that the coal, at times, should be dumped directly into these cars through hoppers in the elevators. The rear legs of the elevators were, therefore, not carried down to the ground, but were supported on wheels on a rail attached to the front walls of the storage buildings, at such an elevation as to leave a clear headway for the cars. The two rails of the track on which the towers moved were thus built at a considerable difference of elevation, and were supported on separate foundations. It should be noted, however, that the coal pockets, to which the upper rail was attached, are unusually substantial structures for buildings of this character. They are built of Monier and Melan construction, and the front walls, particularly, are built of vertical I-beams imbedded in concrete, and stand on pile foundations.

This machinery was erected in 1897, and has been in operation for more than a year.

T. A. COFFIN, M. Am. Soc. C. E.—Attention should be called to some of the sections adopted in the construction of the towers and booms. Mr. Coffin.

The struts which hold the booms out from the tower are of a section which might appear to be peculiar, namely, an I-beam on a channel, both being securely riveted together. By taking moments

Mr. Coffin. about the top point of the boom there is obtained a much larger thrust on these struts than the 20 000-lb. engine pull, and, as they are to receive this live loading directly, they require some attention in their design. When the boom is swung around, these struts, rotating on their pins, pass across the surface of the cross-beam which connects them to the boom. Consequently, only single shear is obtainable at their point of connection, and the strain passes through the lower line of the section, the channel being designed to take the entire strain, and the I-beam holding it horizontal.

This section vibrates very little during hoisting, much less than sections formerly used, and which were composed of two latticed channels.

In order to avoid vibration, which is the disagreeable element in most hoisting towers, tending to make engineers and workmen doubtful of their safety, sections were adopted which promised to insure stiffness as well as strength, in the structure.

All the main members of the towers were composed of latticed channels or beams. These main members were secured at their connections by gusset plates, riveted on either side to the flanges of the channels or beams, thus making every joint a fixed end. Sections plated in that manner take the shake out of the structure, as they are continuous beams.

By comparative estimates of similar towers with others composed of four angles back to back as main members, the weights were found to be nearly the same, but the angle-iron towers had comparatively little stiffness.

In some cases the towers have to be tied down in the rear. This was necessary in this instance, because the tower base was restricted, having only a narrow wharf on which to be operated.

In regard to raising the entire load of 10 000 lbs. for each trip of the shovel, the speaker would call attention to the fact, that, as the weight of the shovel was nearly balanced by a counterweight, the engine had only to raise the coal plus a small fraction of the weight of the shovel.

CORRESPONDENCE.

Mr. Kahn. J. KAHN, Jun. Am. Soc. C. E.—Referring to Mr. Hill's remarks, the steam is conducted to the towers from a central boiler plant situated near the towers. The steam main shown in Fig. 2 leads along the rear of the towers. Steam connections from the engines to the main are made with 3-in. wrought-iron pipe, jointed at intervals with flexible steam joints, which will allow free movement of the towers along the wharf. All pipe is well covered with a non-conducting material, reducing thereby steam condensation to a minimum.

Mr. Hill makes an error in his computations for actual work done by the engine in hoisting the coal. A portion of the weight raised is at all times balanced by the counterweight, and since the weight of the latter is equal to $\frac{8}{10}$ of that of the empty shovel, the actual weight raised before the boom truck is reached is $10\,000 - \frac{8}{10}$ of $6\,000 = 5\,200$ lbs.; and after the boom truck is reached, 7 200 lbs. This, of course, greatly reduces Mr. Hill's approximations of the cost of hoisting.

The question of electric driving was seriously considered before the final arrangement of these hoists was decided upon. The requirements for motors to operate these engines were laid before a number of electrical manufacturing companies, but owing to the irregular working of the engines, together with the large power required, none of these companies cared to undertake the task of equipping the engines.

Briefly, the conditions were as follows: The hoisting engine, working at its normal rate, has a capacity of about 150 H.-P., and its ultimate capacity approaches close to 200 H.-P. It is compelled to change its direction of working twelve times every 50 seconds, the time of one trip. Thus, starting at the beginning of hoisting, it runs forward; slows up as it approaches the boom; stops above the hopper; holding chain drum is here fixed, and hoisting chain drum reverses, allowing the shovel to open; hoisting chain drum is run forward, closing the shovel; engine is stopped for an instant; both drums are reversed, allowing the shovel to descend the boom, at first slowly, then rapidly; holding drum is again fixed, hoisting chain drum reversed, allowing the shovel again to open; holding drum is freed, allowing the shovel to fall into the coal pile; hoisting drum is run forward until the shovel closes; both drums run forward, lifting the filled shovel again toward the boom. All these changes in motion take place every 50 seconds.

It can readily be seen that where so many operations must be performed during such short intervals, it would be a very difficult problem to secure a motor which would work satisfactorily.